CHAPTER 2

WAREHOUSES

2-1. General.

Warehouse design discussed in this manual is intended to provide a dry environment for the purpose of storing goods and material that require protection from the elements. Warehouses must be designed to accommodate the loads of the material to be stored, the associated handling equipment, and the needs of the operating personnel. The design of the warehouse space should be planned to best accommodate the physical dimensions of the material to be stored. The different types of warehouses generally associated with storage depots include heated and unheated warehouses, refrigerated warehouses, and controlled humidity (CH) warehouses.

2-2. Structural requirements.

Design of warehouse structures is to be based on the dead and live load requirements of the structure as it will be built. Snow, wind, and seismic loads shall be considered where they are applicable.

a. Dead load requirements. In general, the dead loads shall be calculated from the weights of all fixed components of the structure including fixed pieces of equipment. Refer to the values given in TM 5-809-1/AFM 88-3 Chap. 1, chapter 3, section 3 for weights of building materials.

b. Floor live load requirements. Live loads to be considered are concentrated wheel loads and uniformly distributed loads, as applicable.

(1) Concentrated loads pertain to any movable point load such as wheel loads from forklift trucks, wheel loads from trailers backed into the building, or any type of movable storage bin on legs. Truck loads within warehouses shall be taken as HS 20-44 loadings of the HB-13, Highway Bridges, published by the American Association of State Highway and Transportation Officials (AASHTO). Loads on railroad tracks within warehouses shall conform to American Railway Engineering Association (AREA) E-80 loading. Concentrated live loads due to forklift wheels can be calculated from mass (weight) data obtained from the forklift manufacturer plus an account of the loads this vehicle is expected to carry.

(2) Uniformly distributed live loads are determined from the type of occupancy expected for the floor. Masses (weights) of materials typically stored in warehouses are given in table 2-1. Live load pressures should be calculated for the maximum loading condition that the warehouse is expected to experience in its lifetime. Quite frequently the type of material stored in a warehouse will be different from that for which it was originally designed. If the material stored is beyond design loads, cracking and settlements can occur in the slab and foundation. As a precautionary measure, the maximum live load pressure for each building area in kilograms per square meter (pounds per square foot) should be displayed on plaques or walls. For design of floors due to heavy loads refer to TM 5-809-12/AFM 88-3, Chap. 15.

Table 2-1. Uniform live load, for storage warehouses.

Material	*Weight per cubic meter (foot) of space kg (lb)*	*Height of pile m (ft)*	*weight per square meter (foot) of floor kg (lb)*	*Live Load kg/m^2 (psf)*
Building materials:				
Asbestos	801 (50)	2 (6)	1465 (300)	
Bricks, building	721 (45)	2 (6)	1318 (270)	
Bricks, fire clay	1201 (75)	2 (6)	2197 (450)	
Cement, natural	945 (59)	2 (6)	1728 (354)	1465 (300)
Cement, portland	1153 (72) to 1682 (105)	2 (6)	2109 (432) to 3076 (630)	to
Gypsum	801 (50)	2 (6)	1465 (300)	1953 (400)
Lime and Plaster	849 (53)	1.5 (5)	1294 (265)	
Tiles	801 (50)	2 (6)	1465 (300)	
Woods, Bulk	721 (45)	2 (6)	1318 (270)	
Drugs, paints, oils:				
Alum, pearl, in barrels	529 (33)	2 (6)	967 (198)	
Glycerine, in cases	833 (52)	2 (6)	1523 (312)	
Linseed oil in barrels	577 (36)	2 (6)	1055 (216)	

Table 2-1. Uniform live load, for storage warehouses—continued.

Material	*Weight per cubic meter (foot) of space kg (lb)*	*Height of pile m (ft)*	*weight per square meter (foot) of floor kg (lb)*	*Live Load kg/m² (psf)*
Rosin, in barrels	769 (48)	2 (6)	1406 (288)	
Shellac, gum	609 (38)	2 (6)	1113 (228)	976 (200)
Soaps	801 (50)	2 (6)	1465 (300)	to
Soda ash, in hogsheads	993 (62)	0.8 (2¾)	815 (167)	1465 (300)
Sulphuric acid	961 (60)	0.5 (1⅝)	488 (100)	
Toilet articles	561 (35)	2 (6)	1025 (210)	
Varnishes	881 (55)	2 (6)	1611 (330)	
White lead, dry	1378 (86)	1.4 (4¾)	1992 (408)	
Dry goods, cotton, wool:				
Burlap, in bales	689 (43)	2 (6)	1260 (258)	
Carpets and rugs	481 (30)	2 (6)	879 (180)	
Coir yarn, in bales	529 (33)	2.5 (8)	1289 (264)	
Cotton yarn, in cases	400 (25)	2.5 (8)	976 (200)	
Jute, compressed	657 (41)	2.5 (8)	1601 (328)	
Linen damask, in cases	801 (50)	1.5 (5)	1221 (250)	
Linen goods, in cases	481 (30)	2.5 (8)	1172 (240)	
Linen Towels, in cases	641 (40)	2 (6)	1172 (240)	
Silk and silk goods	721 (45)	2.5 (8)	1758 (360)	
Sisal, compressed	326 (21)	2.5 (8)	820 (168)	
Tow, compressed	465 (29)	2.5 (8)	1133 (232)	
Groceries, wines, liquors:				
Beans, in bags	641 (40)	2.5 (8)	1562 (320)	
Beverages	641 (40)	2.5 (8)	1562 (320)	
Canned goods, in cases	929 (58)	2 (6)	1699 (348)	
Cereals	721 (45)	2.5 (8)	1758 (360)	
Cocoa	561 (35)	2.5 (8)	1367 (280)	
Coffee, green, in bags	625 (39)	2.5 (8)	1523 (312)	
Dates, in cases	881 (55)	2 (6)	1011 (330)	
Figs, in cases	1185 (74)	1.5 (5)	1806 (370)	
Flour, in barrels	641 (40)	1.5 (5)	976 (200)	1221 (250)
Fruits, fresh	561 (35)	2.5 (8)	1367 (280)	to
Meat and meat products	721 (45)	2 (6)	1318 (270)	1465 (300)
Milk condensed	80 (50)	2 (6)	1465 (300)	
Molasses, in barrels	769 (48)	1.5 (5)	1172 (240)	
Rice, in bags	929 (58)	2 (6)	1699 (348)	
Sal soda, in barrels	737 (46)	1.5 (5)	1123 (230)	
Salt, in bags	1121 (70)	1.5 (5)	1709 (350)	
Soap powder, in cases	609 (38)	2.5 (8)	1484 (304)	
Starch, in barrels	400 (25)	2 (6)	732 (150)	
Sugar, in barrels	689 (43)	1.5 (5)	1050 (215)	
Sugar, in cases	817 (51)	2 (6)	1494 (306)	
Tea, in chests	400 (25)	2.5 (8)	976 (200)	
Hardware:				
Automobile parts	641 (40)	2.5 (8)	1562 (320)	
Chain	1602 (100)	2 (6)	2929 (600)	
Cutlery	721 (45)	2.5 (8)	1758 (360)	
Door checks	721 (45)	2 (6)	1318 (270)	
Hinges	1025 (64)	2 (6)	1875 (384)	
Locks, in cases, packed	497 (31)	2 (6)	908 (186)	
Machinery, light	320 (20)	2.5 (8)	781 (160)	
Plumbing fixtures	481 (30)	2.5 (8)	1172 (240)	1465 (300)
Plumbing supplies	881 (55)	2 (6)	1611 (330)	to
Sash fasteners	769 (48)	2 (6)	1406 (288)	1953 (400)
Screws	1618 (101)	2 (6)	2959 (606)	
Shafting	2002 (125)			
Sheet tin, in boxes	4453 (278)	0.6 (2)	2715 (556)	
Tools, small, metal	1201 (75)	2 (6)	2197 (450)	
Wire cables, on reels			2075 (425)	
Wire, magnet, on spools	1201 (75)	2 (6)	2197 (450)	

Table 2-1. Uniform live load, for storage warehouses– continued.

Material	*Weight per cubic meter (foot) of space kg (lb)*	*Height of pile m (ft)*	*weight per square meter (foot) of floor kg (lb)*	*Live Load kg/m² (psf)*
Miscellaneous:				
Automobile tires	481 (30)	2 (6)	897 (180)	
Automobiles, uncrated	128 (8)		312 (64)	
Books (solidly packed)	1041 (65)	2 (6)	1904 (390)	
Furniture	320 (20)			
Rope, in coils	513 (32)	2 (6)	937 (192)	
Rubber, crude	801 (50)	2.5 (8)	1953 (400)	
Tobacco, bales	561 (35)	2.5 (8)	1367 (280)	

c. Roof live loads. Minimum roof live loads of 98kg/m (20 psf) will be considered for construction and maintenance load roof. Reduction of roof live loads will be permitted based on tributary loaded area and roof slope on any structural member in accordance with TM 5-809-1. This reduction will apply only to supporting structural members.

d. Overhead cranes. For maneuvering large items in storage warehouses, overhead cranes provide mobility without occupying excess storage space for material access. The beams and/or columns supporting the overhead crane must be designed to compensate the additional loads imposed.

(1) *Impact loads.* Increases in design loads for impact include a vertical force equal to 25 percent of the maximum wheel load, a lateral force equal to 20 percent of the mass (weight) of the trolley and lifted load only applied one half at the top of each rail, and a longitudinal force of 10 percent of the maximum wheel load of the crane, applied at the top of the crane rail (TM 5-809-1).

(2) *Moving loads.* Support increases for moving loads are beams-100 percent, columns 80 percent, and foundations, footings and piers — 40 percent (NAVFAC DM-2).

e. Snow loads. The snow load design requirements shall be in accordance with TM 5-809-1. Design considerations shall include the exposure and slope of the roof and its geometric and thermal features. For a roof with a slope less than 40 mm per meter (0.04:1) (½ inch per foot) a surcharge of 8 kg/m² (5 psf) as recommended by ANSI A58.1, should be added to the calculated snow load for rain on snow. Since warehouses in general have large roof areas, it is recommended to include this surcharge in the roof design. If the warehouse being designed is to be an unheated structure, the snow load will most likely be heavier than for a heated structure because of lack of snow melt. The aforementioned are uniform snow loads for flat roofs. If the roof is sloped, a reduction in the design uniform live snow load may be made.

f. Wind loads. Structures should be designed for wind loads in accordance with TM 5-809-1. Design factors shall assume that the wind can come from any direction and that negative pressures (suction forces) act on roofs, eaves, cornices, and walls facing the opposite to the direction of the wind. Exposure "A" should not be used in the design of warehouses in military installations.

g. Seismic loads. Seismic design of warehouses shall be in accordance with the provisions of TM 5-809-10/NAVFAC P-355/AFM 88-3, Chap. 13. Certain warehouse storage areas are considered high risk or essential facilities where damage to the structure could cause particular hardship or danger to life. These structures include flammable storage areas and chemical storage areas. In designing for horizontal seismic loads, these types of structures should be designed with appropriate occupancy importance coefficients as detailed in TM 5-809-10.

2-3. Floor types.

Warehouse floors are constantly subjected to heavy-duty usage; consequently proper floor types are an important consideration in design. Each type has its particular characteristics and is best suited for a particular type of traffic. General warehouse space should be floored with a concrete slab of proper design to carry the wheel loads and withstand the abrasion generated by the continual use of forklift trucks. The constant travel by forklift trucks can deteriorate an unprotected concrete surface, causing dusting and breakdown of the surface. Hardeners and dust proofers are recommended to alleviate this problem: they not only keep down the dust but they generally provide a reflective surface that will aid in more even distribution of lighting. Surfaces that are subject to wetting, such as outdoor docks, should not have a smooth finish to the concrete since this is a safety

hazard and can cause slips and falls to personnel. Float finishing of the concrete or nonslip surface treatments should be used in these areas. Wooden floors are not recommended because of their low wear resistance to industrial traffic and their fire hazard. Office space can be covered with resilient tile or carpet to upgrade the floor slab to office conditions at relatively little expense.

2-4. Doors.

a. Obstructions. The area inside exterior doors leading to dock space is needed for maneuverability of forklift trucks. Building design should take this into account and columns should be planned such that they do not interfere with forklift mobility. Each exterior door should be protected by bumper guards to prevent damage from forklifts. Roll-up doors, or overhead type of doors, consume the least amount of usable warehouse space.

b. Fire doors. In buildings with fire resistance walls (one hour, two hour, or four hour), the properly rated fire doors shall be selected in accordance with the type of fire resistance wall openings.

2-5. Lighting.

Several types of classic designs make good use of natural lighting (fig 2-1). The monitor type of warehouse has windows on both sides and the ends of the raised central portions of the warehouse roof (fig 2-2). This provides good amounts of natural light to central portions of the warehouse. The bilateral building design is achieved by designing windows into the wall of the warehouse at heights just below the roof line (fig 2-3). This design allows light to enter the building above the storage height. Skylights are an additional method of getting natural light to interior areas of the warehouse. This method probably works best when the size of the warehouse is large because the skylights can be placed at any point on the roof of the structure. Artificial lighting in warehouses should be designed in accordance with TM 5-811-2/AFM 88-9.

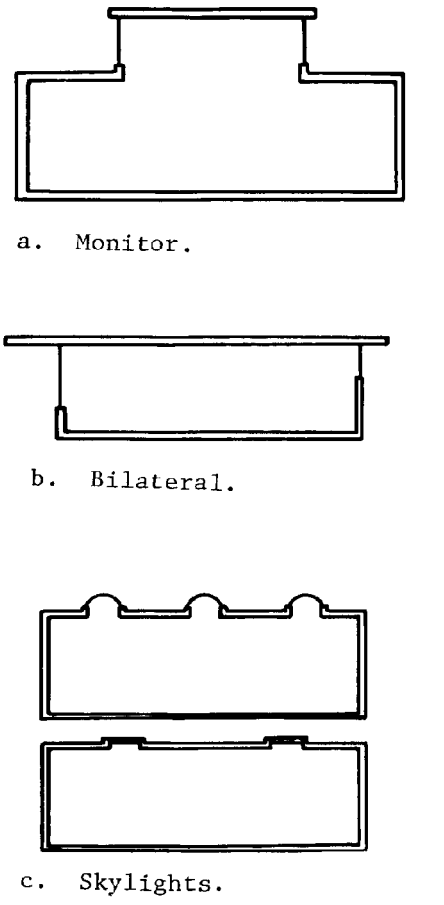

Figure 2–1. Examples of natural lighting designs.

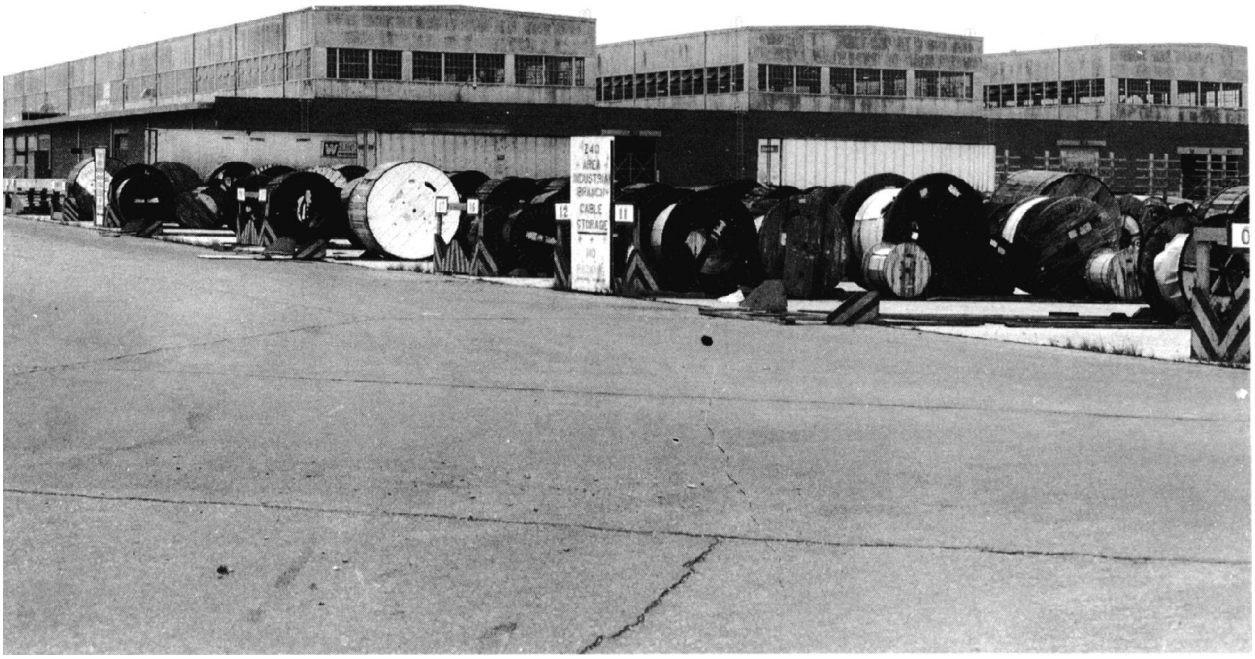

Figure 2-2. Example of monitor type warehouse window design.

Figure 2-3. Example of bilateral type warehouse window design.